




Fluid Therapy: The good, the bad and the ugly

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Objectives

- Distribution of fluids
- Hydration (total body water) compared to perfusion (blood volume)
- Available fluid types, their indications, and potential side effects
 - Crystalloids
 - Isotonic
 - Hypotonic
 - Hypertonic
 - Colloids

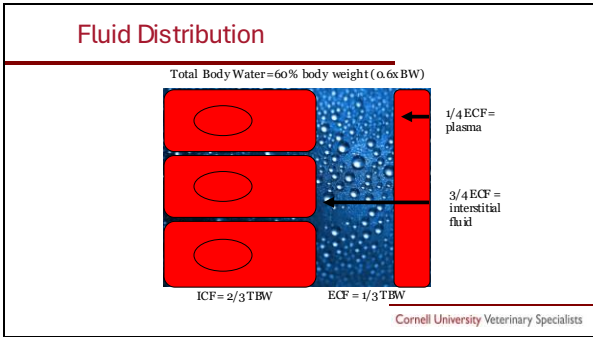


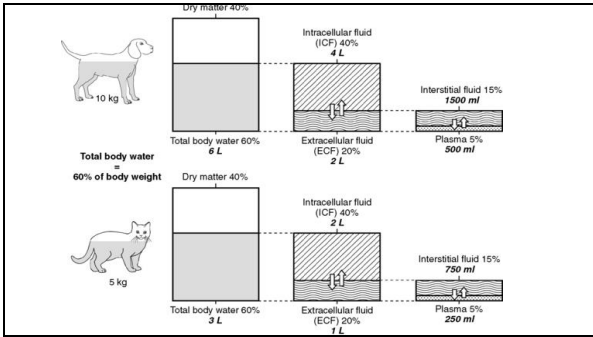
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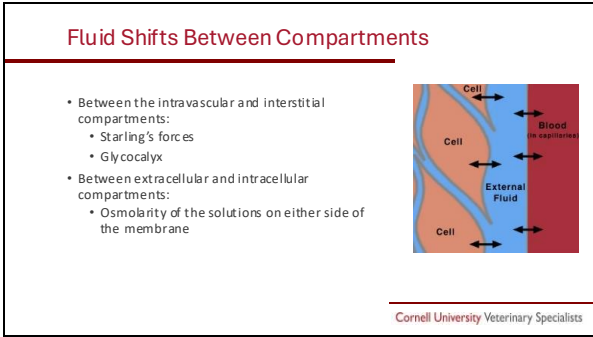
Soapbox

-  Fluids are drugs
-  Significant adverse effects
-  Need to pick the right fluid for the right case
-  If animal is sick, it does n't mean they need fluids

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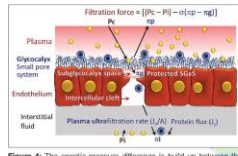






Endothelial Glycocalyx

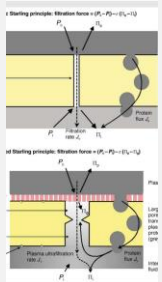
- A protective, gel-like layer on blood vessel walls
- Composed of glycoproteins and proteoglycans
- Key functions:
 - Barrier - prevents leakage of fluids and molecules
 - Inflammation control - reduces inflammatory cell adhesion
 - Blood flow regulation - minimizes friction for smooth flow
 - Coagulation - modulates platelet and clotting activation
- Damage: sepsis, trauma, or ischemia
 - Vascular leakage and organ dysfunction



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Starling's Forces

- Fluid movement across the endothelium depends on:
 - Hydrostatic pressure within the capillary (P_c)
 - Colloid osmotic pressure in the capillary (π_c)
 - Hydrostatic pressure in the interstitial space (P_i)
 - Colloid osmotic pressure of subglycocalyx space



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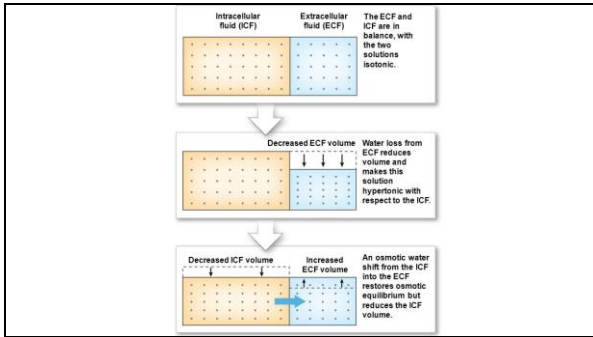
Fluid shifts between extracellular and intracellular compartments

- Cellular membranes are impermeable to most solutes
 - Permeable to H₂O
- Diffusion of H₂O from one compartment to another depends on osmolarity of the compartments
- Osmolarity:
 - Number of particles/L of solution
 - Osmotic effect—can the number of particles make H₂O move across a membrane?
 - Na, K, dextrose

Extracellular fluid	Intracellular fluid
Na ⁺ 145	12
K ⁺ 4	140
Ca ²⁺ 2.5	4
Mg ²⁺ 1	34
Cl ⁻ 110	4
HCO ₃ ⁻ 24	12
H ₂ PO ₄ ⁻ 2	40
Protein ⁺ 15*	90


*15 in interstitial fluid, 15 in plasma
 Figure 1-2 Average values for electrolyte concentrations in extracellular and intracellular fluid. Note the marked concentration differences for many electrolytes.

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Some Normals


- Blood volume:
 - Dog ~90 ml/kg
 - Cat ~60 ml/kg
- Fluid requirements for dogs and cats
 - 30-60 ml/kg/day
 - Can use RER
 - Higher in juveniles (100 ml/kg/day)
- Normal urine production
 - >20-40 ml/kg/day
- Insensible fluid losses
 - Mostly respiratory
 - ~20 ml/kg/day



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Fluid Losses

- Many (most) types of diseases cause fluid losses
- Not drinking/eating
- Gastrointestinal tract
 - Vomiting/diarrhea
- Respiratory tract
 - Panting
- Urinary
 - Polyuria
- Hemorrhage
- "Third spacing"



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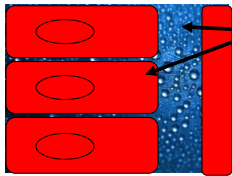
Third Spacing

- Loss of intravascular fluid
 - Can occur due to many causes
 - Inflammation
 - Vascular obstruction
 - Low albumin
- Lost fluid can accumulate in two ways:
 - Excess fluid in interstitium and connective tissues—edema
 - Excess fluid in body cavities—effusion
 - Abdomen
 - Pleural space
 - Pericardial sac



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Fluid losses—Interstitial/Intracellular Space



- Vomiting
- Diarrhea
- Panting
- Fever
- Polyuria

Common terms: dehydration, interstitial dehydration

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Hydration Abnormalities

- Dry mucous membranes
- Decreased skin turgor
- Retracted/sunken eyeballs
- Acute weight loss
- Hypernatremia (especially indicative of intracellular losses, free water loss)

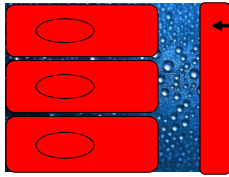


Dehydration	Physical exam findings*
Euhydrated	Euhydrated (normal)
Mild (1–5%)	Minimal loss of skin turgor, semidry mucous membranes, normal eye
Moderate (6–10%)	Moderate loss of skin turgor, dry mucous membranes, weak rapid pulses, enophthalmos
Severe (> 10%)	Considerable loss of skin turgor, severe enophthalmos, tachycardia, extremely dry mucous membranes, weak/irregular pulses, hypotension, altered level of consciousness ^b

*All animals will exhibit all signs.
^bNot all animals will exhibit all signs.

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Fluid losses—Intravascular Space



- Hemorrhage
- Severe dehydration
- Third spacing

Common terms: hypoperfusion, hypovolemia, volume deficit

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Perfusion Abnormalities

Physical Examination

- Mentation
- Quality of mucous membrane refill
- Temp of mm/extremities
- Heart rate
- Pulse quality

Diagnostics

- Blood pressure
- Lactate
- Urine output



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Jack



- 4-year-old MC Labrador
 - Acute onset vomiting & diarrhea after getting into the trash
- PE
 - Dry mms
 - Decreased skin turgor
 - Uncomfortable on abdominal palpation
- Problems
 - Vomiting/diarrhea r/o GI (gastroenteritis, foreign body, parasites) vs. Extra-GI
 - Abdominal pain--r/o GI pain, pancreatitis
 - Dehydration--likely secondary to fluid losses

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Fluid Plan

- Type?
 - Many to choose from
- Route?
 - Subcutaneous, oral, intraosseous, intravenous
- Amount?
 - To bolus or not to bolus (how fluid deficient is the patient)?
 - How to pick a rate of fluids
- Duration?
 - Inpatient/outpatient
 - How fast to replenish dehydration?



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Algorithm for Fluid Therapy

Is the patient hypovolemic?

Yes—bolus

No—calculate fluid requirements

Crystalloids

Colloids

HTS

Blood products

Crystalloids (usually)

Dehydration

Maintenance

Ongoing losses

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Crystalloids

- Inexpensive
- Readily available
- Isotonic
- Hypotonic
- Hypertonic



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Isotonic Crystalloids

- Aqueous solution
- Small particles freely cross the capillary
 - After 1 hour ~ 33% of the infused volume remains in intravascular space
- Replacement or maintenance
- Balanced or...not



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Isotonic Crystalloids—Replacement

- Appropriate for resuscitation
 - Frequently used for rehydration as well
- Composition resembles that of extracellular fluid
- Tend to be higher in Na and frequently contain K, Mg, +/-Ca
- Usually have a buffer
- Normosol R, Plasmalyte A, 0.9% NaCl, Lactated Ringers

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Replacement Crystalloids

Balanced:

- Contain K, Mg, Ca; lower Na, Cl
- Buffers may help correct some abnormalities faster (lactate, gluconate, acetate)
 - LRS
 - Plasmalyte 148
 - Normosol R

0.9% NaCl

- Contains supraphysiologic amounts of Na and Cl
- Doesn't contain other electrolytes
- Acidifying
- Indications:
 - Ionized hypercalcemia
 - Hypochloremic metabolic alkalosis
 - Hypo- or hypematremia

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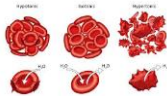
Isotonic Crystalloid—Maintenance

- Replenish hydration (interstitial and intracellular spaces) and provide maintenance fluid needs
 - Appropriate for hypotonic losses
- Usually contain dextrose
- Contain less sodium and more potassium than replacement fluids
- Plasmalyte 56, Normosol-M

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Hypotonic Crystalloids

- Hypermalemia and a free-water deficit
- Helpful for replacing hypotonic fluid losses
- May be safer in renal disease and heart disease
- Maintenance fluids in other patients?
- Low chloride content may be beneficial to reduce bromide loss in seizing patients on KBr
- NEVER use as bolus therapy in resuscitation
 - Lead to cerebral edema
 - Ineffective at expanding IV volume
 - Can cause hemolysis



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Hypotonic Crystalloids

D5W

- Dextrose: 50 g/L (5%)
- 252-278 mOsm/L (Initially isotonic, but becomes hypotonic after metabolism)
- Hypoglycemia correction
- Carrier for medications (e.g., CRI of drugs that require dilution)
- Can help correct hyponatremia

0.45% NaCl

- Na⁺: 77 mEq/L, Cl⁻: 77 mEq/L
- 154 mOsm/L
- Maintenance fluid in patients with sodium-sensitive conditions (e.g., heart or liver disease).
- Can help correct hyponatremia

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Hypertonic Saline

- Exist in several % (most common 3%, 7%)
- Hypovolemic shock, intracranial hypertension, severe hyponatremia
- Small volume, rapid expansion
 - Increased tonicity causes movement of free water from extravascular to intravascular space
 - Expands ECV by 3-5x volume administered
- No more than 1 ml/kg/min
 - Sudden hyperosmolality may stimulate bradycardia and vasodilation
- May lead to RBC crenation and phlebitis
- Other beneficial effects:
 - Arteriole vasodilation, reduced endothelial swelling; weak positive inotropic
 - Immunomodulatory and anti-inflammatory effects (down-regulates IL-1)

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Adverse Effects of Crystalloids

- Short lived intravascular expanding effect
- Fluid intolerance (especially in CHF, decreased COP/vasculitis)
 - Edema—interstitial, pulmonary
 - Body cavity effusion
- Dilution of red blood cells, albumin, coagulation factors
- Shedding of glycocalyx



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Back to Jack!

- Routine gastroenteritis fluid choice
 - Usually go with crystalloid
 - Type dependent on patient's bloodwork
- If electrolytes are normal, choose a balanced replacement crystalloid (Normosol, Plasmalyte)



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Calculating Crystalloid Rates

- Total fluid rate=deficit+maintenance+ongoing losses
- Deficit (L) = % dehydration x body weight (kg)
- Maintenance needs:
 - 30-60 ml/kg/day
- Other ongoing losses—panting, fever, polyuria, diarrhea, gastric residuals
- Correct deficit over 6-24 hours



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Jack (30 kg dog)- Fluid Rate

- Rehydration:
 - 30 kg (7%)= 2.1 Liter deficit = 2,100 mL
 - Replace over 24 hours= 2,100/24= 87.5 ml/hr
- Maintenance:
 - 30 kg x 2 ml/kg/hr = 60 ml/hr
- Total fluid rate:
 - 87.5 + 60=147.5 ml/hr x 1st 24 hours
- Consider ongoing losses!

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Calculating Free Water Deficit

- Free water deficit = TBW (BWx0.6)x [patient serum Na/140- 1]
- Can also provide maintenance fluids in addition to correcting Na deficit
- Correct **slowly** (drop Na by 0.5-2 mEq/L/hr)



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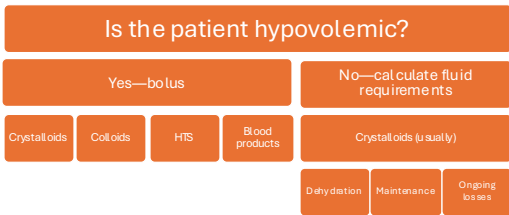
Chloe

- 8-year FS French Bulldog
- History of chronic adipsia—never worked up—owners mix food and water to provide H₂O
- Developed aspiration pneumonia and stopped eating
- PE: 7% dehydration, Temp 102.5 w weight 7.95 kg, bilateral b-lines
- PCV/TS 57%/9 g/dL
- BP 140 mmHg
- Thoracic radiographs—aspiration pneumonia
- Blood gas

Test	Results	Unit	Lowest Value	Highest Value
pH	7.356		7.350	7.450
pCO ₂ (venous)	45.5	mmHg	40	68
pCO ₂ (arterial)	48.2	mmHg	39	47
BE	-8.1	mmol/L	-5	-17
HCO ₃	18.3	mmol/L	18	26
Hb	16.0	g/dL	13.3	20.5
pO ₂ (venous)	76.4	%	76.8	86.8
pO ₂ (a)	72.2	%	85.2	97.8
PCV (%)	57.9	%	13.2	55.0
Plasma	1.0	%	0.12	0.39
Prote	23.5	%	0.90	1.64
Alb	198.8	mmol/L	140	192
K ⁺	4.10	mmol/L	3.5	4.9
Ca ²⁺	1.49	mmol/L	1.2	1.6
Cl ⁻	---	mmol/L	109	120
Glucose	154	mg/dL	65	172
Lactate	0.82	mmol/L	0.5	2.0
FEU	<2	mmol/L	0	2

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Algorithm for Fluid Therapy



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Chloe Fluid Plan

- Maintenance needs:
 - 0.9% NaCl 40 ml/kg/day (could make custom solution isotonic to the patient if Na very high)
- FWD calculation
 - Free water deficit = TBW (BWx0.6)x [patient serum Na/140- 1] =1900 ml
 - Use D5W
 - Replace FWD at 10 meQ/L/day=4 days (96 hours)=20 ml/hr
- Total fluid rate 35ml/hr (20 ml/hr D5W, 15 ml/hr 0.9% NaCl)
- Electrolyte check, weight check q4-6 hours
- So many other questions...

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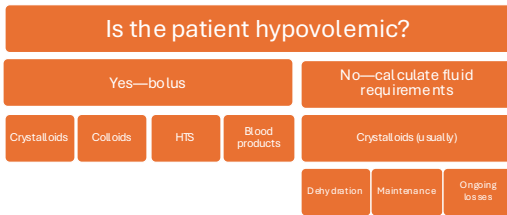
Maggie

- HBC after slipped out of leash 30 min prior to presentation
- PE
 - Temp 97, HR-220 beats/min, sinus, RR 80
 - MMs WHITE, poor pulse quality
 - Doppler BP—50 mmHg
 - POCUS—large abdominal effusion
 - Hemoabdomen
 - PCV/Ts—49%/4.5 g/dL
 - Lactate 8.2 mmol/L (<2.5)



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Algorithm for Fluid Therapy



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Initial Fluid Prescriptions for Shock

- Isotonic crystalloid
 - Total shock dose: 80-90 mL/kg (dog) vs. 50-60 mL/kg (cat)
 - 10-20 mL/kg IV
- Synthetic colloid
 - 5 mL/kg IV
- Hypertonic saline (7%)
 - 3-5 mL/kg
- Blood products
 - If significant hemorrhage/anemia/coagulation abnormalities exist

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Colloid Solutions

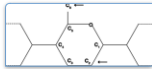
- Solutions that contain large insoluble molecules
- Natural
 - Human serum albumin (HSA)
 - Canine albumin
 - Plasma (fresh, frozen)
- Synthetic
 - Hydroxyethyl starch solutions (HES)
 - Gelatins



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Synthetic Colloids: Composition

- Large starch molecules (MW=10,000 Daltons)
 - Hydroxyethyl starch + isotonic crystalloid
- Cause an increase in blood volume equal to that of the infused volume
 - Retain fluid in the intravascular space
- VetStarch 6% HES 130/04 in 0.9% NaCl
 - 6%: concentration of HES in solution—greater oncotic effect
 - 130 mean MW (kDa)
 - 0.4: degree of molar substitution
 - Varying # of HE residues on an anhydrous glucose molecules
 - Higher # slows rate of destruction more accumulation, slower clearance
- C2/C6 Ratio: higher number—slower rate of destruction



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Synthetic Colloids: Indications

- IV resuscitation, particularly in **hypoalbuminemia** or **increased vascular permeability**
- DOSING:
 - CRI 0.5 to 2 m/kg/hr
 - Bolus: 2-5 ml/kg over 10-30 minutes
 - Ceiling dose: 20 ml/kg/day for Hesperan; 50 ml/kg/day VetStarch
- Refractometer reading of TS is inaccurate after receiving HES

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Synthetic Colloids: Contraindications

- Hypersensitivity
- Inhibition of endogenous albumin production
- Coagulation effects
 - Dilution of platelets, factors
 - Interfere with platelet function, vWF, factor VIII
- Higher incidence of AKI in humans with sepsis treated with synthetic colloids
 - Osmotic nephrosis
 - Decreased GFR
 - Conflicting evidence in vet med

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Crystalloids vs. Colloids in Veterinary Shock Resuscitation

- **Tale-ho me message**
 - Crystalloids remain the foundation of shock resuscitation; should be used carefully
 - Colloids have limited but selective roles (e.g., hypoproteinemia, small-volume resuscitation)
 - Blood products are superior in hemorrhagic shock and should be prioritized
 - Over-resuscitation is harmful—monitor perfusion and adjust accordingly
- **Judicious fluid therapy is key**
 - Excessive fluid administration worsens morbidity
 - Goal-directed resuscitation is emphasized
 - Bolus approach (10 mL/kg crystalloids, 3-5 mL/kg colloids) with reassessment is preferred over large-volume rapid infusions

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Damage Control Resuscitation in Animals

- **Early use of blood products** rather than excessive crystalloid therapy
- **Balanced transfusion approach** (~1:1 ratio of PRBCs to plasma if needed)
- **Controlled fluid administration** to avoid hemodilution and increased bleeding
- **Monitor perfusion parameters:** Mentation, CRT, lactate, blood pressure, PCV/TP and coagulation status
- **Avoid fluid overload**, which can lead to **hemodilution and worsening bleeding**
- **Temperature control is critical**—hypothermia worsens coagulopathy in veterinary patients as in humans

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Maggie's Initial Resuscitation

- HTS 7% 5 ml/hr over 10-15 min
 - +/-crystalloid bolus—Plasmalyte 10 ml/kg
- pRBCS
- Fresh frozen plasma (thawed plasma available at CUVS)



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When to STOP Fluids

- When patient is euhydrated and can maintain euhydration
 - No or compensated losses
 - Adequate UOP and fluid/food intake
- With signs of impending volume overload
- Taper?
 - Renal disease or insufficiency
 - Avoidance of medullary washout
 - Usually slow taper if high fluid rates for a long time



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Thank you?

QUESTIONS?
